Motivating Participants in Human-based Evolutionary Computation Systems

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***Abstract*—Human-based evolutionary computation (human-based EC), which uses humans as executors of all evolutionary operators, can solve problems for which only humans can judge the quality of solutions. In human-based EC systems, when participants who join problem solving are fixed, the upper limit of search performance of the human group should be unpredictable but roughly implicitly decided. Therefore, unlike standard EC using computers, human-based EC systems need to enhance or maintain motivations of participants for contributions to derive better search performance of the group. In the paper, we propose two methods for motivating participants in human-based EC systems. The first method is meant to enhance motivations by differentiating participants. More precisely, it feedbacks rankings on the number of times of producing and evaluating solution candidates to participants in a realtime manner. The second method is meant to maintain motivations by equalizing participants. More precisely, it sets the maximum allowed number of times of producing and evaluating solution candidates equally to all participants. It can also theoretically shorten a time period for problem solving. The two methods are strategically contrary to each other. We reveal though experiments that the first method enhances motivations of participants and also that systems using the second method and not using it produce same quality of solutions. These results suggest that we should feedback another rankings which are not based on the number of times to participants while using the second method to obtain high quality of solutions in a short period of time.**

***Index Terms*—humans, evolutionary computation, motivation, creativity, problem solving**

I. Introduction

Evolutionary computation (EC) is a framework of optimization methods that model genetics and evolution. Many algorithms based on the concept of EC have been developed. There are two main steps in EC, namely selection, which mimics natural selection, and operations, which mimic crossover and mutation. These steps can also be viewed as actions of agents, and thus the entire EC can be viewed as a multi-agent system [1]. In human-based EC, human agents perform the selection as well as the operations [1]. Since human-based EC has humans produce and evaluate solutions, it can solve problems in human organizations for which only humans can evaluate the quality of solutions. Human-based EC can be applied to complex problems such as global warming.

Human-based EC systems can be either centralized or decentralized. Centralized human-based EC systems [2] manage all solutions created by humans and share them among humans in central locations, such as a web page. In decentralized human-based EC systems [3], [4], humans manage their own solutions and share them with other humans in local areas through direct connections. Solutions can be shared over a mobile ad-hoc network formed by wireless communication devices.

In human-based EC systems, many humans execute all evolutionary operators as mentioned above. So, there exist differences between human-based and standard ECs and are summarized in Table I. In human-based EC systems, when participants who join problem solving are fixed, the upper limit of search performance of the group of the participants should be unpredictable but roughly implicitly decided. Therefore, in order to derive better search performance of the group, we need to enhance or maintain their motivations to contribution to the problem solving as shown in the item (5) of Table I

In the paper, we propose two methods for enhancing or maintaining motivations of participants in human-based EC systems. In addition, we implement each method into the human-based EC system that we developed in our latest work [5] and examine each method through experiments with the system. The first method is meant to enhance motivations of participants by differentiating participants. More precisely, it feedbacks rankings on the number of times of producing or evaluating solution candidates to participants in a realtime manner. The second method is meant to maintain motivations by equalizing participants. More precisely, it sets the maximum allowed number of times of producing and evaluating solution candidates to all participants. It can also theoretically shorten a time period for problem solving. The two methods are strategically contrary to each other.

The remainder of this paper is organized as follows. In Section II, we briefly review related researches. In Section III, we explain the human-based EC system into which each of the two proposed methods is implemented. Section IV describes the first proposed method and shows experimental results with the system using the first method. Section V

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TABLE I
DIFFERENCES BETWEEN HUMAN-BASED AND STANDARD ECS.

		Standard EC	Human-based EC
(1)	Kinds of agents	Computer(s)	Humans
(2)	Evaluation criteria for agents	Identical	Different
(3)	Methods for producing solutions by agents	Identical	Different
(4)	Time variation of agent characteristics	No	Yes
(5)	Motivations of agents for contributions	Not necessary	Necessary

describes the second proposed method. Finally, Section VI presents conclusions and suggests areas for future research.

II. RELATED RESARCHES

The human-based genetic algorithm (GA) [1], a type of human-based EC, was first applied to problems for which the problems themselves and their solutions must be described in natural language [1], [6]. In this application, the human-based GA used a centralized online message board to manage communication among human agents. The applications of the human-based GA are not limited to those that involve natural language. One study [7] compared an interactive and a human-based GAs in terms of their ability to solve problems not described in natural language. It was shown that crossover and mutation operations performed by human agents are useful for solving such problems.

The GA framework has been utilized for modeling creative problem solving processes in human organizations [6], [8]. In [6], components and procedures in human organizations were considered to be genes, individuals, population, selection, crossover, and mutation in a GA. In [8], a data mining technique was applied to discussions by people on an online message board to find solutions to a given problem. Words important for problem solving, considered to be building blocks in a GA, were extracted and then fed back to participants in real time. This procedure was iterated to produce better solutions by combining obtained building blocks, which is considered to be crossover in a GA.

Creative activities of humans have been modeled as EC in several studies [9]–[11].

In [9], the authors chose the design of an advertisement to be published in a social network service as a task for a human-based EC system and then compared two types of human-based EC systems with a method in which each person independently thinks of a design. One type of systems relied only on crossover for creation of new solutions (i.e., new solutions were created by combining two existing solutions). The other type of systems relied only on mutation (i.e., new solutions were created by modifying an existing solution). The designs created by the two systems were subjectively evaluated in terms of divergence, relevance, and effectiveness by people who had not participated in the problem solving.

In [10], the authors proposed a general procedure to realize a crowd-sourcing-based design and allowed human-based EC as an option in a step of the procedure. In addition, they first considered a generative design task, where humans provide design purposes and constraints and then computers generate a variety of designs meeting these purposes and constraints, for crowd-sourcing according to the proposed procedure. Then, they proposed a crowd-sourcing-based method to reasonably evaluate the quality of the created designs. In the evaluation method, people who had participated in the crowd-sourcing evaluation first created multiple criteria for evaluating the quality and then ranked the designs based on these criteria. The method was shown to give rankings closer to those of experts compared to a method in which people freely ranked the designs. This method is applicable to human-based EC, which relies on human subjective evaluations of solutions.

In [11], the authors conducted simulations of human-based EC in which various humans were modeled in terms of fitness functions and behaviors in solution evaluation and creation, and then made three hypotheses on the relationship between the characteristics of a human group that executed the human-based EC and problem solving performance. Next, they conducted experiments to validate the three hypotheses. The hypotheses were roughly (1) a homogeneous human group in terms of the degree of problem understanding yields better performance, (2) a well-balance human group in terms of the ratio of people who mainly try to create solutions and who mainly try to evaluate solutions yields better performance, and (3) the use of various evolutionary operators yields better performance.

III. OUR PREVIOUS HUMAN-BASED EC SYSTEM

Each of the two methods for motivating participants is implemented into the human-based EC system that we developed in our latest work [5]. In this section, we describe the human-based EC system.

A. Representation of Solutions

For problems that occur in human organizations, some solutions can be represented by a few words whereas others require long sentences. Therefore, to apply a human-based EC system to a wide variety of problems, we adopt two representations for solutions, namely tags and sentences. A tag is a summary of a solution. Tags are displayed in a tag cloud. Sentences provide the details of a solution. When an appropriate representation of a solution is a tag, sentences can be used to explain the reason why the solution is recommended.

B. Interface for Displaying and Evaluating Solutions

A solution to a problem is represented by a tag and sentences, as mentioned in Section III-A. Solutions represented

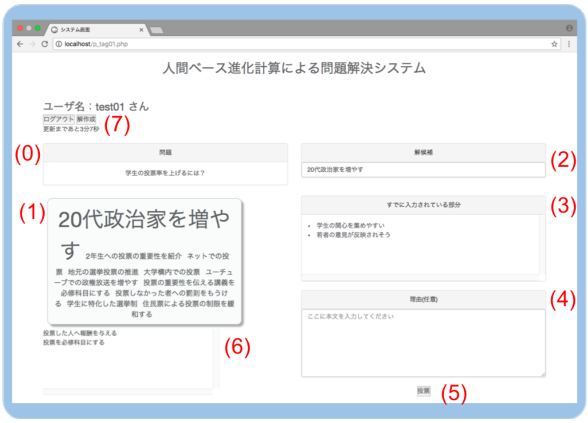

Fig. 1. The main window of the human-based EC system. Labels (0) to (7) are used for explanation and are not included in the actual system.

by tags are displayed in a tag cloud. Figure 1 shows the main window of the system. The widget labeled (0) displays the problem to be solved and that labeled (1) is the tag cloud.

When a solution represented by a tag in the tag cloud is clicked, the clicked tag is displayed by the widget labeled (2) and a solution represented by sentences is displayed by the widget labeled (3). New sentences can be added to solutions using the widget labeled (4) by any user. In general, new sentences are added to existing solutions as supplementary explanations.

To evaluate a clicked tag as being good, a user can click the vote button, which is the widget labeled (5). The fitness value of the clicked tag is then increased by one. A user who participates in problem solving can evaluate a given solution just once in a generation. A fitness value of every solution is set to zero at the beginning of a generation. A larger fitness value indicates a better solution. When the vote button is clicked, new sentences, if any, are added to the solution.

The font size of a tag in the tag cloud is dynamically changed based on the tag's fitness value. To determine the font size of a tag, we first transform the fitness value, f, to a relative fitness value, F, according to Equation (1).

$$F = \frac{f - f_{min}}{f_{max} - f_{min}}, \tag{1}$$

where f_{max} is the current largest (best) fitness value among all tags and f_{min} is the smallest (worst) current fitness value. The font size for displaying the tag is then based on F as follows. When $0.0 \leqq F \leqq 0.2$, the font size is 16 points. When $0.2 < F_n \leqq 0.4$, the font size is 18 points. When $0.4 < F \leqq 0.6$, the font size is 26 points. When $0.6 < F \leqq 0.8$, the font size is 32 points. When $0.8 < F \leqq 1.0$, the font size is 48 points. However, if $f_{max} = f_{min}$, which includes the situation where the fitness values of all tags are set to zero at the beginning of a generation, all tags are displayed using the font size of 26 points.

The maximum number of tags displayed in the tag cloud is 10.

C. Interface for Displaying Solutions in a Queue

As mentioned in Section III-B, the interface for displaying tags is the tag cloud and the maximum number of tags in the tag cloud is 10. Tags created when the tag cloud is already full are placed in a queue in the order they were created. However, since we assign a fitness value of one to a solution created during a generation, if there are tags with a fitness value of zero in the tag cloud, one of them is replaced by the created tag (its fitness value is one). The removed tag, whose fitness value is zero, gets placed at the start of the queue. The tags in the queue are displayed by the widget labeled (6) in Figure 1. Thus, participants can see all tags in the queue. We can expect that these tags also give ideas to participants. However, participants cannot see sentences corresponding to a tag in the queue.

We can evaluate tags in the queue during a generation. To do this, we first input the name of the target tag in the queue using the widget labeled (2) and then click the vote button. The fitness value of the target tag is then increased by one. Then, if there are tags with a fitness value less than that of the target tag in the tag cloud, one of them is replaced by the target tag and the removed tag from the tag cloud gets placed at the start of the queue.

D. Interface for Creating Solutions

To obtain the information required for tracing the evolution of solutions from participants, which is described in Section III-E, the interface for creating solutions is displayed in an independent window.

Specifically, when the "Create solution" button (widget (7) in Figure 1) is clicked, a new window is shown for creating solutions, as shown in Figure 2. The interfaces for inputting a solution as a tag and sentences are labeled (8) and (9) in the new window, respectively. The widget labeled (10) is used for selecting any number of existing solutions that influenced the present solution creation. We explain this in Section III-E. The input solution is confirmed by clicking the "Creation" button. Other solutions can be created at any time in this window. To return to the main window shown in Figure 1, the user clicks the "Return" button (widget (12)). The created solution can be only a tag (sentences are not required).

As mentioned in Section III-C, a newly created solution is assigned a fitness value of one at the time of creation, so that if there are any solutions with the fitness value of zero in the tag cloud at the moment of creation, one of them is replaced by the newly created solution. The removed tag gets placed at the start of the queue.

According to the concept of human-based EC, solution creation by participants is regarded as the use of operations (crossover and mutation) in EC.

E. Interface for Obtaining Information for Tracing the Evolution of Solutions

The widget labeled (10) in the window for solution creation shown in Figure 2 is used to select an arbitrary number of

Fig. 2. The window used for solution creation. The labels (8) to (12) are used for explanation and are not included in the actual system.

Fig. 3. The main window of the human-based EC system implementing the method for differentiating participants.

present solutions (i.e., tags currently in the tag cloud) that influenced the present solution creation.

F. Generation Gap Model

The generation gap model is introduced to give all created solutions equal opportunity to be evaluated and to lower the dependency of the survival probability of a solution on the timing of its creation (i.e., solutions created earlier are more likely to survive). In the generation gap model, the mechanism used to replace tags in the tag cloud by tags in the queue tries to give equal opportunity of evaluation. In addition, the mechanism used to reset the fitness values of all solutions created so far at every generation tries to remove the dependency on creation timing. The procedure of the generation gap model is as follows.

1) When the upper limit of the number of tags that can be displayed is reached, any additional tags are stored in the order in which they are created (i.e., they are stored in a queue).
2) A fixed period of time (for example, 10 minutes) is considered to be one generation.
3) When the present generation becomes the next generation, a fixed percentage, $X\%$, of the displayed tags with the lowest fitness values are replaced by the same number of tags from the queue in the order they were created. In the system, we set X to 50%. If there is an insufficient number of tags in the queue to replace 50% of the tags in the cloud, the number of tags replaced is the number of tags in the queue.
4) At the beginning of each new generation, the fitness of all tags in the tag cloud is set to zero.

IV. Differentiating Participants to Motivate Them

A. Method

Some of on-line games on the Internet announce names or IDs of some better players with respect to scores to all players in the games. This kinds of announcements would motivate players to play them harder.

Similar to the way above, our proposed method here announces better participants with respect to the degree of contribution to problem solving to all participants in a human-based EC system. More concretely, the method displays a fixed number of participants who produce a greater number of solution candidates and who evaluate a greater number of ones to all participants in a human-based EC system in a realtime manner. This method aims at inducing more contributions from already higher contributors, that is to say, the top-up effect.

In addition, the method displays rankings among all participants on the number of times of producing and evaluating solution candidates individually to each participant. In the method above for the top-up, only some participants can know their rankings. So, the method enables all participants to individually know their rankings. The method aims at rousing participants, that is to say, the bottom-up effect.

The two types of rankings are displayed simultaneously to each participant. Figure 3 shows the main window of the human-based EC system implementing the method. The rankings are shown at the bottom of the main window.

B. Experiment for Examining the Effect

1) Procedure: Participants who join the experiment are 16 Chinese university students. The participants are divided into two groups, Group 1 and Group 2. Each group consists of eight people. We set two problems to solve, Problem 1 and Problem 2. These problems are as below.

Problem 1:
Suppose that a university student is intended to make personal connections to enrich a university life. The student affords to use around 10 thousands Japanese yen (around 100 US dollars) every month. What should the student do for his/her purpose?

Problem 2:
Suppose that a university student who lives alone is intended to keep good health. The student affords to use around 10

thousands Japanese yen (around 100 US dollars) every month. What should the student do for his/her purpose?

Then, the experimental procedure is as follows. Also, the parameter settings of the human-based EC system used for the experiment are shown in Table II. We refer to the human-based EC system using the proposed method for differentiating participants as the new system and to the system not using it as the old system hereinafter.

1) Group 1 searches for the solution to Problem 1 by the new system while Group 2 searches for the solution to Problem 1 by the old system.
2) Group 1 searches for the solution of Problem 2 by the old system while Group 2 searches for the solution to Problem 2 by the new system.
3) Questionnaires below are given to the participants:
   a) Which system made you more creative, the new system or the old system?
   b) Which system made the group more creative, the new system or the old system?
   c) Which system motivated you for contributions more highly, the new system or the old system?
4) For nine pairs between the three best solutions to Problem 1 obtained with the new system and those obtained with the old system, eight people who do not join the problem solving answer which solution is practical and also which solution is creative on a five grande evaluation. The eight people do the same thing with Problem 2.

TABLE II
THE PARAMETER SETTINGS OF THE HUMAN-BASED EC SYSTEM USED FOR THE EXPERIMENT.

Parameter	Value
the number of generations	5
the duration of one generation (minute)	4
the maximum number of tags displayed in the tag cloud	10
the replacement percentage of tags in the tag cloud (%)	50

2) Results: The replies to the questionnaire from the participants in the step 3) are summarized in Table III. Also, the replies to the questionnaire from the eight people in the step 4) are summarized in Table IV, in which the new and old systems are compared from the practical or creative viewpoint and for each viewpoint, totally 144 ($9 \times 8 \times 2$) comparisons are done to the two systems.

TABLE III
THE RESULTS OF THE QUESTIONNAIRES.

Question	The old system	No difference	The new system
a)	2	1	13
b)	2	4	10
c)	1	2	13

We apply the sign test with a significance level of 5 % to those results and realize that for all three questions, there are statistically significant differences between the two systems.

TABLE IV
THE RESULT OF THE QUESTIONNAIRE TO THE OTHER PERSONS

	The new system $\leftarrow$ $\rightarrow$ The old system				
	-2	-1	0	+1	+2
Practicality	8	32	10	35	59
Creativity	49	34	27	16	18

These results suggest that the new system that differentiates participants with rankings can make people more creative and make them be more motivated for contributions.

Also, we apply the Wilcoxon test with a significance level of 5 % to the results of the step 4) and realize that there are statistically significant differences between the two systems for both practical and creative viewpoints. The new system is better in terms of creativity and the old system is better in terms of practicality. The results suggest that as a result that the new system can make people more creative and make them be more motivated for contribution, the new system produces better solutions from the creative viewpoint.

Figures 4 and 5 shows the changes in the number of times of the solution production and evaluation over generations to Problems 1 and 2, respectively. We can observe from Figures 4 and 5 that the there are not so much differences in the number of times of producing and evaluating solution candidates between the new and the old systems. Also, we recognize that the number of times of evaluating solution candidates by Group 1 is less than that by Group 2 in both problems. It is suggested from those observations that even if participants are motivated by the proposed method, the number of times of producing or evaluating solution candidates never drastically increases or decreases.

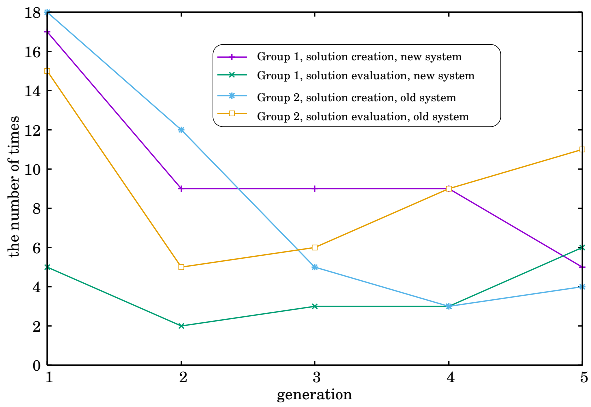

Fig. 4. The changes in the number of times of the solution production and evaluation over generations to Problem 1. Group 1 used the new system without restriction and Group 2 used the old system.

V. EQUALIZING PARTICIPANTS TO MOTIVATE THEM

A. Method

During discussions for problem solving in human organizations in face-to-face, some particular people can frequently

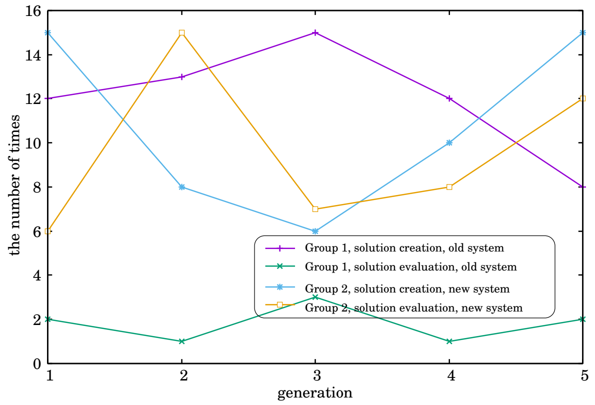

Fig. 5. The changes in the number of times of the solution production and evaluation over generations to Problem 2. Group 1 used the old system and Group 2 used the new system.

speak due to their active personalities or due to their higher posts. In such situations, some people who have quiet personalities or are at the lower posts can avoid saying anything. Giving equal opportunity for speaking to all people would encourage them to contribute to the problem solving.

Based on the idea above, we propose a method for equalizing opportunity for contribution to problem solving in the human-based EC system among all participants. More concretely, the method sets the maximum number of times of producing solution candidates to be N_p and that of evaluating them to be N_e. These are parameters of the method and we use $N_p = 1, N_e = 1$ in the paper.

Figure 6 shows the situation that someone is stopped to produce a solution candidate by the method in the human-based EC system. More precisely, it shows the situation that when the person is about to produce a solution candidate at the second time by pushing the button of "Producing a solution candidate", the method stops it while displaying "You are allowed to produce a solution candidate at most once per generation". Also, Figure 7 shows the situation that someone is stopped to evaluate a solution candidate by the method in the human-based EC system. More precisely, it shows the situation that when the person is about to evaluate a solution candidate at the second time by pushing the button of "Evaluating a solution candidate", the method stops it while displaying "You are allowed to evaluate a solution candidate at most once per generation".

B. Experiment for Examining the Effect

1) Procedure: Participants who join the experiment are 15 Japanese university students. The participants are divided into two groups, Group A and Group B. Group A consists of eight people and Group B consists of seven people. We use the same two problems to solve as described in Section IV, Problem 1 and Problem 2.

Then, the experimental procedure is as follows. The parameter settings of the human-based EC system used for the

Fig. 6. The situation that someone is stopped to produce a solution candidate because he/she already reaches the maximum allowed number of times of producing a solution candidate.

Fig. 7. The situation that someone is stopped to evaluate a solution candidate because he/she already reaches the maximum allowed number of times of evaluating a solution candidate.

experiment are the same as in Table II. We refer to the human-based EC system using the proposed method for equalizing participants as the system with restriction and to the system not using it as the system without restriction.

1) Group A searches for the solution to Problem 1 by the system without restriction while Group B searches for the solution to Problem 1 by the system with restriction.
2) Group A searches for the solution of Problem 2 by the system with restriction while Group B searches for the solution to Problem 2 by the system without restriction.
3) After the experiment, questionnaires are given to the participants as below：
   a) Which system made you more creative, the system without restriction or the system with restriction?
   b) Which system made the group more creative, the system without restriction or the system with restriction?
   c) Which system gave you more mental stresses, the system without restriction or the system with restriction?
4) For nine pairs between the three best solutions to Problem 1 obtained with the system without restriction and

TABLE V
THE RESULTS OF THE QUESTIONNAIRES.

Question	without restriction	No difference	with restriction
a)	13	1	1
b)	7	2	6
c)	3	4	7

TABLE VI
THE RESULT OF THE QUESTIONNAIRE TO THE OTHER PERSONS.

	without restriction ←			→ with restriction	
	-2	-1	0	+1	+2
Practicality	24	19	23	22	38
Creativity	27	24	26	17	32

those obtained with the system with restriction, seven people who do not join the problem solving answer which solution is practical and also which solution is creative on a five grande evaluation. The seven people do the same thing with Problem 2.

2) Results: The replies to the questionnaire from the participants in the step 3) are summarized in Table V. Also, the replies to the questionnaire from the seven people in the step 4) are summarized in Table VI, in which the systems without restriction and with restriction are compared from the practical or creative viewpoint and for each viewpoint, totally 126 ($9 \times 7 \times 2$) comparisons are done to the two systems.

We apply the sign test with a significance level of 5 % to the results shown in Table V and realize that only for the question a), there is a statistically significant difference between the two systems. Also, we apply the Wilcoxon test with a significance level of 5 % to the results shown in Table VI and realize that there is not a statistically significant difference between the two systems for either practical or creative viewpoint.

The above results indicate that while participants can be more creative in the system without restriction, there is no difference of the quality of produced solutions between the two systems. In the system with restriction, participants could feel boring after finishing one time of producing and evaluating a solution candidate, and that would result in making them less-creative. However, since, in that system, participant can spend enough time for one time of producing and evaluating a solution candidate, although every participant has just one opportunity in every generation, the quality of the production and evaluation would be assured.

Table VII shows some reasons for answers to the question c) in the step 3). We can find the reasons that the restriction afforded him/her to carefully think about him/her and others solutions' and also that time was left too much in a generation after he/she finished the production and evaluation of solution candidates. These reasons support our thought that the restriction assures the quality of producing and evaluating solution candidates by participants.

Finally, Figures 8 and 9 show the changes in the number of times of the solution production and evaluation over generations to Problems 1 and 2, respectively. We can observe from those figures that in the system with restriction, the participants did not always produce or evaluate a solution candidate once, which was the maximum allowed number of times. We imagine that although the participants had only one opportunity to produce and evaluate a solution candidate in a generation, they did not produce a solution candidate when they did not think of good one and did not evaluate one when they did not find good existing one. In addition, we imagine that enough time for the production and evaluation made them behave in such a way. However, for both two problems, the group using the system without restriction produced and evaluated solution candidates a greater number of times than that using the system with restriction. We imagine that the participants felt themselves creative at the moment that they could produce or evaluate many solution candidates and that results in the answers to the question a). On the other hand, as for the question b) that asks which system made your group more creative, there is possibility that the participants regarded producing high quality of solutions as group's creativity. So, the answers to the question 2) might come from that. We should have given the meaning of "creative" to the participants in advance of the experiment. We will consider this issue in our future work.

TABLE VII
SOME REASONS FOR ANSWERS TO THE QUESTION C) IN THE STEP 3).

Because I was embarrassed by the situation that multiple similar solution candidates were present in the system with restriction.
Because I had nothing to do after finishing my production and evaluation of solution candidates in the system with restriction.
Because time was left too much after I finished the production and evaluation in a generation in the system with restriction.
Because I felt the anxiety that my solution candidate was buried in many others ones unless I produced mine with haste in the system without restriction. Meanwhile, I had time to carefully think about my and others solution candidates in the system with restriction.

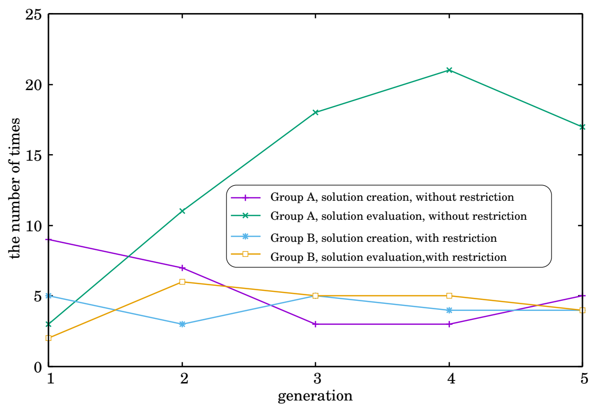

Fig. 8. The changes in the number of times of the solution production and evaluation over generations to Problem 1. Group A used the system without restriction and Group B used the system with restriction.

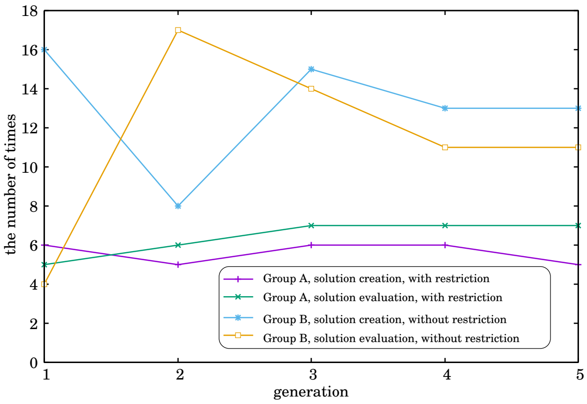

Fig. 9. The changes in the number of times of the solution production and evaluation over generations to Problem 2. Group A used the system with restriction and Group B used the system without restriction.

VI. Concluding Remarks

We implemented the method that decides rankings of participants with respect to the number of times of producing and evaluating solution candidates and announces the rankings to all participants in a realtime manner during problem solving into our previously developed human-based EC system. Then, we examined the effect of the method through the experiment and questionnaires. The results suggested that the human-based EC system using the method, which is one of the methods for differentiating participants, makes participants more creative and be more motivated.

Also, we implemented the method that equally sets the maximum allowed number of times of producing and evaluating solution candidates in a generation to all participants into our previously developed human-based EC system. Then, we examined the effect of the method through the experiment and questionnaires. The results suggested that the human-based EC system using the method, which is one of the methods for equalizing participants, can produce same quality of solutions as the system not using it. That means that the system using the method would be able to produce same quality of solutions as the system not using it in a shorter period of time if we set a time duration of a generation appropriately.

These two results above integratively suggest that in the human-based EC system, we should feedback another rankings which are not based on the number of times of producing and evaluating solution candidates to participants while giving the same maximum allowed number of times to all participants. Such a human-based EC system would enable us to obtain high quality of solutions in a short period of time.

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